ITEA Journal 2010; 31: 18–21

Development and Fielding of a Direct Methanol Fuel Cell

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Fuel cells are developing as one of the most promising and suitable energy sources for many military applications. The U.S. Army Operational Test Command required and contracted for a low-power, 250-W transportable direct methanol fuel cell to power operational test instrumentation in support of the future combat systems test and evaluation. This unit also has application by the German Bundeswehr as a battery-charging station and auxiliary power unit. The direct methanol fuel cell is characterized by its low noise emission, minimal thermal signature, and high fuel efficiency that will enable continuously sustained operation for long-duration missions in the field.

Key words: Energy sources; environmental experiments; nonintrusive power; operational realism; noise; T&E; thermal signature.

Test instrumentation requirements demand nonintrusive power. If nonintrusive power is not used, the test scenario will be interrupted with negative effects on operational realism and possible loss of data. Use of vehicle power to support test instrumentation has three deficiencies: (a) the vehicle may not have adequate power for both tactical equipment and test instrumentation, (b) use of test instrumentation during periods of *Silent Watch* will drain the batteries and require startup of the vehicle to charge the batteries and interfere with the tactical mission, and (c) previous tests demonstrated that tactical power was not stable for test instrumentation. When standalone batteries are used, life-cycle cost analysis indicates an increase in expense for support personnel costs and equipment, and interruption of each battery-equipped vehicle for a battery exchange every 8–12 hours during the operational test. A better alternative was required.

Acquisition of a nonintrusive power source required a number of complementary tasks: (a) survey of available fuel cell industry sources to determine if the technology had reached sufficient maturity to support operational test requirements, (b) construction of an experimental prototype fuel cell to determine if an operational fuel (fuel cell *stack*, fuel container, startup battery, and balance of plant components) could be integrated into a single enclosure, (c) an independent technology assessment to determine if specifications were realistic, and (d) preparation of specifications and source selection. Based on best value, the FC-250 direct methanol fuel cell was selected. The contract award specified three-phase procurement: (a) prototype phase for 4 units, (b) low-rate initial production for up to 20 units, and (3) full-production phase. The prototype phase has been completed successfully with almost 2,000 hours of operational life, and the low-rate initial production phase is in process for delivery in mid-2009.

The specifications for the alternative power source fuel cell were detailed, but general enough to encourage a variety of fuel cell technologies to be proposed. Principal objectives were focused on power output, size, and weight. The use of containers of pressurized fuel was prohibited because of the nature of the operational test environment (the fuel cell would be mounted on the exterior of a vehicle). Secondary concerns were about survivability (shock of 30g, vibration profiles for tracked and wheeled vehicles, and drop tests) as specified in MIL-STD-410F. Range of operating temperature, emitted noise level, and thermal signature were also specified consistent with the operational test environment.

Contractor development and testing

A contract was awarded to Smart Fuel Cell AG of Munich, Germany, in November 2006, which proposed development and construction of the prototype FC-250 DMFC. The technology was based on an expansion of their commercial fuel cell product, the EFOY 1600, into

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE **Development and Fielding of a Direct Methanol Fuel Cell**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Operational Test Command,91012 Station Avenue,Fort Hood,TX,76544-5068**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Figure 1. FC-250 fuel cell field testing at USAOTC.

a fully integrated package. Smart Fuel Cell AG built and tested two proof-of-concept prototypes and demonstrated them in early 2007. They also visited the U.S. Army Operational Test Command (USAOTC) at Fort Hood, Texas, in April 2007 for a form, fit, and function check. This visit resulted in a number of technical changes to make the unit more compatible with the operational test environment.

Smart Fuel Cell AG then built two fully operational prototypes and subjected them to laboratory testing to validate hardware, firmware, and software performance prior to testing of the prototypes at the Bundeswehr Technical Research Center in Meppen, Germany. Prototype performance testing was conducted in November 2007 and February 2008. The units had performed well in the laboratory but failed when subjected to the survivability tests. Support mounts (designed for the commercial environment) broke, and other elements could not withstand the 30g shock and drop tests. However, a 24-hour dust test was successful, and the unit did not seem to be susceptible to light rain. Noise and thermal signature were minimal and exceeded specifications. In February 2008, the tests were repeated at Meppen. The FC-250 passed all tests successfully and continued to operate. The only damage noted was small indentations at each corner where the unit had been dropped. Based on these results, the FC-250 met the definition for Technology Readiness Level 6 (TRL 6)—System/subsystem model or prototype demonstration in a relevant environment: *Representative model or prototype system, which is well beyond the breadboard level, is tested in a relevant environment and represents a major step up in a technology's demonstrated readiness*.

Testing at the USAOTC

The U.S. Army recognizes four instrumentation support applications for nonintrusive power fuel cells: (a) the FC-250 for large vehicles and power for mobile ground instrumentation, (b) a lightweight alternative power source for smaller vehicles and unmanned systems, (c) a commercial fuel cell in an enclosed box for low-power fixed-site application, and (d) a wearable power source to support soldier-carried instrumentation. Both the FC-250 and the commercial fuel cell are currently in use.

Four prototype FC-250 fuel cells were delivered to the USAOTC in April 2008. Custody and operation of these units was accepted by the USAOTC Test Support Contractor (TSC). The TSC personnel then installed an FC-250 fuel cell and operational test instrumentation on two test support vehicles (modified high mobility multiwheeled vehicles—*Figure 1*), which were operated for 600–800 hours on rough terrain trails at the Fort Hood, Texas, range areas. Both units operated without failure throughout the test period. No fuel cell in this power range has yet been operated successfully for such an extended duration.

A third unit is presently undergoing extended life-cycle testing to determine when the power output degrades to 80% of its normal output. For a normal maximum output of 250 W, the degraded value is 200 W. Based on observed data from individual modules, it is expected that this value may approach or exceed 5,000 hours. The performance objective in the specification was 3,000 hours.

Field and laboratory testing by the TSC revealed some hardware and firmware anomalies—not a surprising result for a new prototype. However, the fuel cells continued to operate and provided data to confirm successful continued performance. At the conclusion of the field testing in July 2008, the TSC concluded and stated that the FC-250 was at Technology Readiness Level 7 (TRL 7)—*System prototype demonstration in an operational environment*:

Figure 2. Dingo 2 vehicle.

Prototype near or at planned operational system, represents a major step up from TRL 6 requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle, or space.

Testing by the Bundeswehr Test Centers

Within the German Bundeswehr there will be two applications for a 250-W fuel cell system. The first application will be the use of the fuel cell system FC-250 as an energy-platform for a battery-loading station for mobile and stationary use in the field, as well as for use in vehicles. Possible users will be soldiers of the German Bundeswehr, e.g., the Infantrymen of the Future (Infanterist der Zukunft) and the soldiers of the German Special Forces.

In the second application, the FC-250 fuel cell system will be used as a charging device for the reloading of batteries in vehicles. Because of the integration into a vehicle (space problems), the system has to be split into an energy unit and a tank unit. This project is still in its study phase. There are plans to do the field testing with vehicles like the wheeled vehicle, Dingo 2, shown in *Figure 2*.

To conduct laboratory testing, German Bundeswehr WTD 41 acquired three FC-250 fuel cell systems within the study budget, sponsored by BWB (Federal Office of Defense Technology and Procurement). With these fuel cell systems, WTD 41 accomplished a test program, harmonized with the firm, Smart Fuel Cell AG *(Figure 3)*.

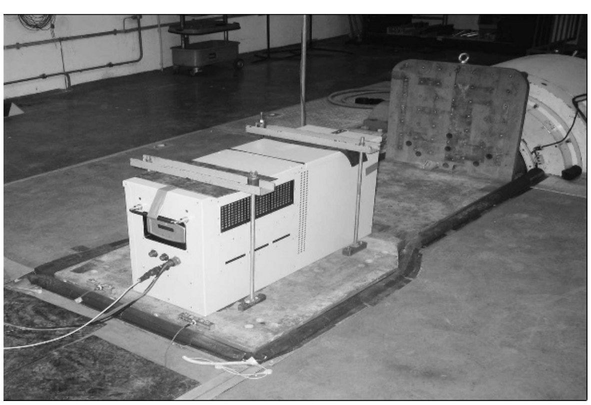

Figure 3. Fuel cell system FC-250 undergoing vibration testing.

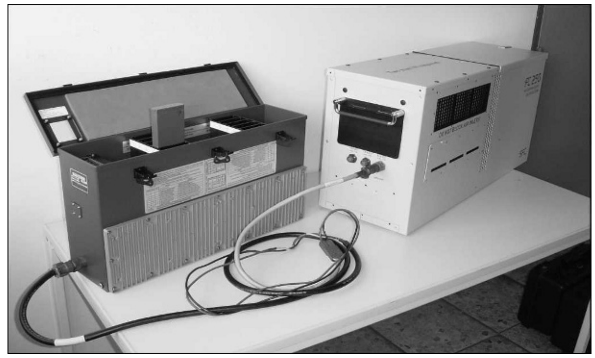

Figure 4. FC-250 with modified battery loading unit type PP–8481B/U.

The testing included the fuel cell system as a single unit as well as its coaction with the modified battery-charging unit, Type PP–8481B/U, from Bren-Tronics, Inc., a battery manufacturer in the United States *(Figure 4)*.

WTD 41, in collaboration with Smart Fuel Cell AG, carried out the tests in *Table 1*. The laboratory tests in principle proved the fuel cell system FC-250 to be an appropriate power source but also disclosed that subsequent improvements to the fuel cell system still need to be done. The testing of the modified battery-loading unit, Type PP-8481B/U, from Bren-Tronics, Inc., was successfully completed by the manufacturer. After realization of the improvements by Smart Fuel Cell AG, verification tests will be accomplished by WTD 41 in cooperation with USAOTC.

Field deployment and test support

In 2009, FC-250 fuel cells were installed on vehicles under test to provide uninterrupted power for operational test instrumentation. The units

Table 1. Test conditions and results

	Results	
Test	Passed	Failed
Function test	×	
Cold start test	×	
Temperature test	×	
Freeze and thaw test (at −10°C, system start after thaw to +10°C)	×	
Dust test		×
Shock and vibration test	×	
Electromagnetic compatibility test		×
Spray water test		×
Noise emission analysis	×	
Drop test	×	

operated for approximately 500 hours over an 11-week period without failure. They were exposed to direct sunlight with measured temperatures exceeding 140°F (60°C) on a solar shield placed above the fuel cell lid and 135°F–138°F on the fuel cell side panels. Although these temperatures exceeded the operating limit of the fuel cell (118°F; 50°C), the fuel cells were unaffected and provided the power required at a substantially reduced test cost compared with batteries. This was the first field deployment during an extended event of a 250-W fuel cell in the Department of Defense. The FC–250 fuel cell has satisfied the intent of the DoD definition for Technology Readiness Level 8/9—

TRL 8: Actual system completed and 'flight qualified' through test and demonstration. Technology has been proven to work in its final form and under expected conditions.

TRL 9: Actual system 'flight proven' through successful mission operations. Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation.

Conclusion

This article presents the results of recent successful environmental tests of a 250-W direct methanol fuel cell conducted at test range facilities in Fort Hood, Texas, and Munich, Meppen, and Trier, Germany, as a cooperative effort by USAOTC, BWB/WTD 41, and Smart Fuel Cell AG (manufacturer of the FC-250 direct methanol fuel cell). Contractor tests included power output to various applications, cold start test, temperature test, freeze and thaw test (at −10°C, system start after thaw to +10°C), static orientation test, shock and vibration test, drop test, spray water test, noise emission analysis, and an electromagnetic compatibility test. During government field and laboratory tests, the FC-250 was connected to typical instrumentation and battery charging applications in the operational environment. These tests demonstrated the reliability and maturity of the FC-250 technology and validated its performance at Technology Readiness Level 7.

The cooperative testing resulted from a formal data exchange agreement in support of testing of mutual interest and exchange of test data. This exchange is favorable for both nations because in the context of this international cooperation, common methodologies will be employed and thus synergistic effects will be obtained with economic advantages for both parties. In addition, the assessment of the functional reliability of the direct methanol fuel cell system will be expanded through the extensive breadth and variety of test situations. The goal for military equipment users—which is to get proven and reliable portable fuel cells into operational use—will be achieved much earlier.

As mentioned, the successful support and reliable field performance in a rugged tactical environment demonstrates that fuel cells can be an alternative source of power for test and evaluation requirements. Using fuel cells reduced interruptions to the tactical timeline during operational testing and is a cost effective measure for future tests. ❑

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Acknowledgments

Many people contributed to the successful development of the FC-250 fuel cell. These people include Mr. Wynn Atterbury, then at the U.S. Department of Defense Test and Evaluation/Science and Technology program; initial sponsors and Mr. Michael Stanka of the Future Combat Systems Combined Test Organization, who provided key support and guidance during formulation of the technology assessment and development of the acquisition strategy; Dr. S. R. Narayan and Mr. Thomas Valdez of the Jet Propulsion Laboratory, who built the first medium-power all-in-one fuel cell; Dr. Steven Zakanyzc, Science Advisor from the Institute for Defense Analyses; Herr Christian Boehm, Frau Carola Voglhuber, and Freulein Sevilay Kaya from Smart Fuel Cell AG; and Mr. Jackie Zajicek, Mr. Elmer Johnson, Mr. J. B. Brown, and Mr. Nathaniel Bradley of the USAOTC, Test Support Contractor.